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Does Trade Liberalization Harm the Environment? A New Test

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Abstract

Recent events such as the NAFTA and the completion of the Uruguay Round have raised concern over the impact of trade liberalization on the environment. In particular, it is believed that less stringent environmental standards in developing countries will give them a comparative advantage in pollution-intensive goods. Using single equation models, existing empirical studies have found either no relationship between environment and trade flows, or a positive relationship between trade liberalization and the environment. This paper develops a simultaneous-equations model to estimate this relationship, directly incorporating the effects of openness on growth of income, and of income growth on environmental damage. A two-good trade model with endogenous factor supply is estimated using pooled provincial data on Chinese water pollution from 1987-1995. Estimation of this model reveals that trade liberalization directly aggravates environmental damage via its influence on the terms of trade, but indirectly mitigates it via its effect on income growth. Simulations suggest that trade reform during the period may have had a net beneficial impact on emissions growth.

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I. Introduction

Industrial countries have recently raised concerns over whether or not "dirty industries" migrate. The concern has focussed on a perceived loss of comparative advantage in these industries because of more stringent domestic environmental regulations compared to developing countries. Developing countries, in contrast, are concerned that trade liberalization will promote specialization in dirty industries, thus aggravating environmental damage (Dean l992a,b).

Theoretically, the impact of trade liberalization on pollution levels is not clear. Consider the "ability to pollute the environment" as an input into the production process. Relatively lenient environmental regulations would mean that the use of the environment is relatively cheap to the firm. In the standard Heckscher-Ohlin trade model, a country with such a relatively low factor price ratio (or relatively large physical stock of a factor) would be classified as relatively

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"environment" abundant. Freer trade would then lead to increased specialization in pollution-intensive goods. This environmentally detrimental shift in the composition of output lies behind the popular concern. Yet, following the Stolper-Samuelson theorem, the price paid for using the environment would be bid up (assuming the externality was internalized), and all firms would shift to less pollution-intensive production techniques. In the standard HO model, there would be no change in the overall use of the environment.

However, if the inverted-U hypothesis is correct (Grossman and Krueger, 1995; Selden and Song, 1994), the amount of environmental damage in a country at any point in time is *endogenous*, and depends upon the income level of the country. According to this literature, income growth has three effects on the existing amount of pollution emissions. Greater economic activity raises demand for all inputs, hence increases emissions (the "scale effect"). But, if people increase their demand for a clean environment as income rises (i.e., if clean environment is income elastic), then they will only tolerate higher levels of pollution if the effluent charge is higher. Since higher effluent charges encourage firms to shift toward cleaner production processes, this "technique effect" tends to reduce emissions. Finally, if income growth shifts preferences toward cleaner goods (i.e., if clean goods are relatively income elastic), then the share of pollution-intensive goods in output will fall. This "composition effect," therefore, tends to decrease emissions. The inverted-U hypothesis argues that at low levels of income, the scale effect outweighs the composition and technique effects, creating a positive relation between income growth and environmental damage. At some higher level of income, however, the latter two effects outweigh the former. Thereafter, increased income leads to a net reduction in environmental damage.

Copeland and Taylor (1994) show that relatively low income could give a country a comparative advantage in pollution-intensive goods, even if environmental damage costs were optimally internalized, since clean environment is a normal good. They then argue that freer trade will raise income, resulting in scale and technique effects which offset each other. The net impact on environment is, therefore, determined by the composition effect. Thus, trade liberalization will promote the growth of environmental damage in the poorer countries. But, if a country is on the right side of the inverted U, then freer trade should on net inhibit the ability to pollute-- reducing the "supply of environment" available for production and, thus, reducing a country's comparative advantage in pollution-intensive goods. This favorable outcome is even more likely if more open economies actually do grow faster, due to access to better technology or exposure to global competition (Dollar, 1992; Harrison, 1996; Edwards, 1992). Countries presumably find themselves moving over the inverted-U faster, increasing the likelihood that rising incomes will cause pollutant levels to fall.[2]

The few econometric studies[3] which attempt to answer this question find some counter-intuitive results. Tobey (1990) and Grossman and Krueger (1993) focus on the composition effect of freer trade. They investigate the impact of environmental regulations on trade flows in the context of a Heckscher-Ohlin model. The stock of environment (assumed to be exogenous) is treated as an additional input which, along with labor, capital, and natural resources should affect the pattern of trade. Both these studies find that trade flows are unaffected by relative

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[2] As Birdsall and Wheeler (1992) note, if foreign technology is cleaner, or exports must be cleaner to meet higher foreign standards, then more open economies would see cleaner growth.

[3] For a more in-depth review of these studies, see Dean (1996, 1998). For surveys of the overall literature, see (Dean, 1992a; Jaffe, et al., 1995).

environmental abundance. Lucas, Wheeler and Hettige (1992) focus directly on the toxic intensity of output, rather than on trade flows. They find that the growth rate of toxic intensity of manufacturing output is lower for rapidly growing open economies compared to those which are closed. Thus openness appears to contribute to cleaner growth.

In the most ambitious study thus far, Antweiler, Copeland, and Taylor (1998)[4], develop a theoretical model to decompose the change in emissions (from income growth) into scale, composition effects, and technique effects (extent of abatement). They then estimate changes in SO_2 emissions using a single equation reduced form model, and pooled cross-country time series data from the GEMS dataset. The authors acknowledge that such an estimation will not distinguish the extent to which trade policy has affected emissions, since trade policy itself will generate the three effects above. From separate estimates, they find that trade liberalization does shift the composition of output towards dirty goods for low income countries. However, the magnitude of this effect is small. In addition, when composition effects are added to indirect calculations of the impact of trade liberalization on scale and technique, the authors find that trade liberalization appears to be "good for the environment."

Clearly, the relationship between trade liberalization and environmental damage is more complex than is allowed for in these one-equation models. This paper develops a simultaneous equations model which incorporates both the direct and indirect interrelationships between trade, environment, and growth. As in much previous literature, the environment is modeled as a productive input. However, its supply is endogenous, and can, therefore, be affected by trade policy. The implications of this for empirical tests are demonstrated using the special case of a

[4]This paper was done concurrently with Antweiler, Copeland, and Taylor (1998).

two-good, small country trade model, with endogenous factor supply. In this special case, a two-equation simultaneous system is required to capture both the direct and indirect effects of trade liberalization on growth of environmental damage.

This system is then estimated using pooled provincial level data on Chinese water pollution for 1987-1995, from a new World Bank dataset. Since China is one of the few developing countries which has had an extensive water pollution levy system in place for some time (Wang and Wheeler,1996), we might have some confidence that it has successfully internalized some of the costs of this pollution. In addition, reliance on pooled provincial data should yield a closer approximation to the experience of one country over time.

Results show strong support for the idea that trade liberalization actually has both a direct and an indirect effect on emissions growth, and that these effects could be opposite in sign. It appears that China has a comparative advantage in pollution-intensive goods, and thus increased openness directly aggravates environmental damage. At the same time, increased openness strongly raises income growth. Income growth itself has a strong negative effect on emissions growth. Thus trade liberalization indirectly mitigates environmental damage. To assess the net impact of trade liberalization, counterfactual simulations are run, assuming that China's foreign exchange liberalization of 1991 never took place. For a large number of Chinese provinces, these simulations suggest that emissions per unit of industrial value-added would have grown more rapidly had there been no liberalization policy. Hence, the net effect of trade liberalization may indeed be "good for the environment."

II. A General Model of Trade and the Environment

Suppose real output (Y) is a positive function of the stock of conventional factors of production, labor (L) and capital (K), and the ability to generate environmental damage (D):

$$Y = A(t)h(L, K, D) \tag{1}$$

where $h_1 > 0$, $h_2 > 0$, $h_3 > 0$ (and subscript i refers to the derivative of the function with respect to argument i). As in Dollar (1992), Harrison (1996) and Edwards (1992), a more restrictive trade regime (higher t) is assumed to reduce total factor productivity ($A' < 0$).

Though K and L are assumed to be fixed in supply, the equilibrium level of D is endogenous. The derived demand for D is a function of the emissions charge, t, Y, and the share of pollution-intensive goods in real output, O:

$$D = f(t, Y, O) \tag{2}$$

where $f_1 < 0$, $f_2 > 0$, and $f_3 > 0$. The variable supply of D is determined by consumers" willingness to

tolerate environmental damage. One way to model this is analagous to variable labor supply and the labor/leisure tradeoff. Let utility be a positive function of goods and clean environment, E. Then $D = \bar{E} - E$, where $\bar{E}$ is the total stock of environment. Utility maximization yields consumer demand for E, and therefore their willingness to supply (tolerate) D. Equation (3) shows the inverse supply curve for D.

$$t = g(D, Y) \tag{3}$$

Consumers will only allow higher levels of D if firms pay a higher charge ($g_1 > 0$). Assuming clean environment is a normal good, an increase in income raises demand for E, and hence reduces supply of D ($g_2 > 0$).

The share of pollution-intensive goods in total output:

$$O = z(t,Y) \tag{4}$$

will be negatively related to income as long as clean goods are relatively income elastic, (z_2<0). For a country with a comparative advantage in pollution-intensive goods, an increase in trade restrictiveness will also shift production toward relatively cleaner goods (z_1<0).

If we totally differentiate the system in (1) - (4) we can solve for the static effect of trade liberalization on emissions:

$$(dD/dt)\cdot? = -hA'(f_1g_2 + f_2 + f_3z_2) - f_3z_1 \tag{5}$$

where ? < 0 is the determinant of the system. The second term on the right side of (5) is the effect of trade liberalization on the demand for environment (as an input) due to a change in the composition of output. If a country's comparative advantage is in pollution-intensive goods, $z_1<0$, and thus $-f_3z_1>0$. Thus, increased openness would aggravate environmental damage. Counteracting this is the first term which captures the fact that trade raises income. The sum in parentheses shows the technique, scale, and composition effects, respectively, of an increase in income due to trade liberalization. If we are on the "right" side of the inverted U, this sum is negative. With A'<0, the first term is negative. Therefore, even if comparative advantage leads to specialization in pollution-intensive goods, the impact of trade on income could dominate, leading to lower emissions overall.

The commonly used set of assumptions on production and consumption listed below (Copeland and Taylor l994, Lopez l994) can be shown to rule out the beneficial effect of trade liberalization on the environment:

A1. Constant returns to scale in production
A2. Elasticity of substitution between factors of production equal to one.
A3. Strong separability between goods and pollution in utility
A4. Homothetic preferences among goods.

A4 is sufficient to preclude any composition effect of income growth ($z_2 = 0$). Given A1, A3, and A4, the increase in emissions due to the scale effect will be proportionate to the rise in income ($f_2(Y/D)=1$). The impact on emissions of the technique effect will be inversely proportional to the change in income, given A2 and A4 ($f_1(t/D)=-1$). Finally, the equilibrium emissions charge will also increase proportionately with income, given A3 and A4 ($g_2(Y/t)=1$), assuming the marginal disutility of environmental damage is constant with respect to the level of D (i.e., assuming $g_1=0$). As noted by Copeland and Taylor, these assumptions imply that the scale and technique effects generated by a rise in income exactly offset each other.[5]

Together these assumptions imply that there can be no inverted U. We have $(dD/dY)(Y/D)=(f_1g_2 + f_2 + f_3z_2)(Y/D)=0$. Hence, an increase in income due to more open trade could never reduce environmental damage. Given this, the effect of more open trade on the composition of output becomes the sole determinant of damage level (as in Copeland and Taylor, 1994). Going back to (5), the entire first term on the right side goes to zero. Thus, (dD/dt)@? $=-f_3z_1$.

Lopez emphasizes two things as being critical to ensure that growth could lead to less environmental damage. One is an income elastic demand for clean goods (non-homothetic preferences). This ensures that income growth has a composition effect: $f_3z_2 < 0$. The other is greater elasticity of substitution between inputs in production. This increases the size of the technique effect (f_1g_2), making it possible for it to outweigh the scale effect. The strength of the

[5] If $g_1 > 0$, then marginal disutility from damage rises with the level of damage. In this case, the technique effect of a rise in income (via more open trade) will partly offset (or reinforce) the composition effect. But the effect of the latter will still dominate.

technique effect is further enhanced if $g_1 > 0$, i.e., the marginal disutility from environmental damage is an increasing function of damage level.[6]

III. An HO Model with Endogenous Factor Supply

To illustrate the importance of accounting for the relationships given by (1)-(4) in empirical testing, consider the following special case. Suppose we consider a small country which produces two types of goods, dirty (X_1) and clean (X_2). There is no transborder pollution or consumption pollution. Thus all emissions are generated by production. As in Lopez (1994), production in each sector uses both conventional factors of production (K, L) and D:

$$X_j = A(t)h_j\,[F(L,K),\,D] \qquad (5)$$

where $h_j\,(\cdot)$ is concave in $F(\cdot)$ and in D, and characterized by constant returns to scale in K, L, and D (j= 1,2). The production function in (5) assumes weak separability between conventional factors of production and emissions. I.e., the marginal rate of technical substitution between K and L is assumed to be independent of the level of D. Dirty goods are defined as those which are relatively pollution-intensive. Thus, production of X_1 uses a higher ratio of D to conventional factors at any given factor price ratio than production of X_2. Let $F(\cdot)$ be an aggregator of the stock of conventional factors.

We assume this country has a relative abundance of environment, and therefore a comparative advantage in dirty goods. The costs of environmental damage are internalized via emissions taxes (t). Though the country is trading initially, there exists some level of trade restrictions on imports of X_2.

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[6] In our notation, using (1) and (2), $dD = [1/(1-(f_1g_1)]f_3dO<f_3dO$.

With these simplifying assumptions, we can set out an HOV trade model which captures the relationships in (1)-(4), using the approach developed in Jones (1965). Nominal income growth, $\hat{Y}_N$, may be expressed as:

$$\hat{Y}_N = a_1 \hat{p}_1 + a_2 \hat{p}_2 + a_1 \hat{X}_1 + a_2 \hat{X}_2$$

where a_i (a_j) is the share of input i (sector j) in total output, and ^ is proportionate change. Using (5), real income growth may then be expressed as:

$$\hat{Y} = a_D \hat{D} + a_F \hat{F} + \hat{A} \qquad (6)$$

As in Edwards (l992), suppose at any time T, $A_T = A_o e^{ßT}$, where ß is a linear function of t, and ß' < 0. Then (6) may be written

$$\hat{Y} = a_D \hat{D} + a_F \hat{F} + b(t) \qquad (7)$$

The unit cost functions for X_1 and X_2 relate goods prices and factor prices,

$$(\hat{t} - \hat{w}) = (1/|q|)(\hat{p}_1 - \hat{p}_2) \qquad (8)$$

where: p_j are domestic prices of good j; w is the wage paid to conventional factors; $?_{ij}$ is the share of input i (i=F,D) in unit cost of output j, and ¦?¦=($?_{D1}$-$?_{D2}$)>0. Equation (8) captures changes in the derived demand for inputs as a function of changes in relative goods prices (assuming fixed stocks of factors of production). Since the country is small, changes in the composition of domestic demand do not affect relative outputs nor relative factor demands (i.e., there is no composition effect of income growth).

Martin and Neary (1980) develop a simple way of integrating variable labor supply into the HO model. Using a similar methodology, we can incorporate a variable environment supply.

Write the supply of D as D=?(t ,p_1, p_2,Y_N). Totally differentiating and writing in proportionate change, we have:

$$\hat{D} = e_t \hat{t} + e_{D1} \hat{p}_1 + e_{D2} \hat{p}_2 + e_Y \hat{Y}_N \quad (9)$$

where e_t , e_{D1} , e_{D2} , are own price elasticities and e_y is income elasticity. Assuming that consumers" demand for E (supply of D) is homogeneous of degree zero in income and prices, and substituting for changes in commodity prices from (7), we can write (9) as:

$$\hat{D} = e_{tw}(\hat{t} - \hat{w}) - e_Y \hat{Y} \quad (10)$$

where e_{tw} is a reduced form environment supply elasticity with respect to changes in relative factor prices.[7] If the supply curve does not bend backward, $e_{tw} > 0$. Since clean environment is a normal good, $e_y < 1$. Thus, a rise in income reduces the amount of damage individuals are willing to allow at any price t .

Substituting (8) into (10) yields the equilibrium rate of change in emissions:

$$\hat{D} = (e_{tw} / |q|)(\hat{p}_1 - \hat{p}_2) - e_Y \hat{Y} \quad (11)$$

Together, equations (7) and (11) form a simple simultaneous system describing the rates of change in equilibrium environmental damage and equilibrium real income. In this system, trade liberalization affects the growth of environmental damage in two ways. Since ($\hat{p}_1$ -$\hat{p}_2$) = ($\hat{p}_1$*-$\hat{p}_2$*-$\hat{t}$) (where * indicates world prices), a reduction in trade restrictions will raise the relative price of dirty goods (11), leading to increased specialization in these goods. This *composition effect* should increase the growth of environmental damage directly. However, lower levels of trade restrictions will raise factor productivity and thereby income (7). This

[7] e_{tw} = [e_t?$_{F2}$ + (e_{D1+} e_y a_1)¦?¦].

increase in income will reduce the growth of environmental damage, since it reduces the willingness of individuals to supply the environment as a factor of production at any given t (*technique effect)*. Estimating a two-equation simultaneous model such as this would allow one to sort out these two effects. Since they work in opposing directions, a one equation model with trade restrictiveness as an explanatory variable may simply yield an insignificant coefficient.

Notice that it is possible for the composition effect of trade liberalization to actually be beneficial for the environment. With constant returns to scale, changes in the composition of output can be expressed as:

$$\hat{X}_1 - \hat{X}_2 = (1/|l|)(\hat{D} - \hat{F}) + s_s|q|(\hat{t} - \hat{w}) \tag{12}$$

where: s_S is the elasticity of substitution along the production possibility frontier; $?_{ij}$ is the share of total I used in producing j, and ¦?¦=($?_{D1}$-$?_{D2}$)>0. Substitute (7), (8), and (10) into (12). With some simplification this yields:

$$\hat{X}_1 - \hat{X}_2 = \tilde{s}_s(\hat{p}_1 - \hat{p}_2) - |l|^{-1} Z^{-1}[(1 + a_F e_Y)\hat{F} + e_Y b(t)] \tag{13}$$

where: $\tilde{s}_s = s_s + Z^{-1}(e_{tw}/|l||q|)$

$Z = (1 + a_D e_Y)$

Equation (13) shows that reductions in trade restrictions will again have two opposing effects on the relative growth of the pollution-intensive sector. On the one hand, by increasing the relative price of X_D, trade liberalization induces more than the usual increase in output of X_D, since increased demand for D raises the equilibrium quantity of D. This is shown by $\tilde{s}_s$, which is the elasticity of substitution along the *variable* factor production possibility frontier. If backward bending supply curves are ruled out, $\tilde{s}_s > s_S$. Note that this effect is diminished by a feedback effect due to income growth, captured by Z. On the other hand, trade liberalization induces income growth which reduces the equilibrium quantity of D. This is seen in the third term on the right side of (13). Therefore, increased openness could actually lead to a reduction in the share of pollution-intensive goods in output, if the indirect effect of trade liberalization on income growth, and therefore on the quantity of environmental damage, is stronger than the direct effect on the composition of output.

IV. An Application to China

Ideally the hypotheses presented above should be tested using data from one country over time. However, lengthy time series data on environmental damage are rare. A new World Bank dataset[8] has become available which provides provincial level data on environmental, regulatory, and socioeconomic data for China from 1987 to 1995. According to Wang and Wheeler (1996) China has had an extensive water pollution levy system in place for some time. Most of China's counties and cities have implemented the system, and levies have been imposed on about 300,000 firms. Fees are paid by an enterprise when its effluent discharge exceeds the legal standard. Effluent standards vary by sector and fees vary by pollutant. New penalties have been imposed since 1991, including a levy on all wastewater discharge, as of 1993. Since China has been somewhat successful in internalizing environmental damage from water pollution into the costs of firms, equations (7) and (11) are estimated using these pooled data, with environmental damage defined as water pollution emissions (measured in tons of COD discharge).

[8] These data are compiled from several official Chinese sources which are described in Wang and Wheeler, 1996.

Data

Tables 1 and 2 show some of the trends in water pollution at the provincial level, as well as trends in other explanatory variables. Table 1 shows a wide variation in the average annual growth of total industrial COD discharge (measured in tons) with most provinces showing some increase. However, table 2 shows that by the end of the period, discharge intensity (tons of COD per million yuan of output) fell dramatically in all but two provinces. Table 2 also reveals large increases in the total levies collected across most provinces during the period. Thus, despite the fact that the amount of wastewater discharged rose in most provinces, it appears that firms have responded to the levies by cleaning up wastewater.

Since emissions data are limited to the industrial sector, income is measured as the value of industrial output in 1990 constant yuan. Most provinces show quite high average annual growth rates of industrial output. Data on a broad set of factors of production are not available at the provincial level. Therefore, the traditional factors of production included in the model are simply the labor force and physical capital stock. Average annual rates of investment are consistently high across provinces, whereas rates of change in employment are low and show little variation.[9]

Dasgupta, Huq, and Wheeler (1998) argue that the degree of state ownership in the industrial sector affects the impact of the levy system. They note that SOEs are likely to have higher pollution-intensity, since they are less efficient in production. In addition, SOEs may be less responsive to increased pollution charges if they face soft budget constraints. Table 1 shows that provinces vary greatly in the percent of industrial value-added coming from SOEs. However,

[9]This is probably because total provincial employment was used, due to incomplete data on

table 2 shows that virtually all provinces experienced a decrease in the percent of value-added from SOEs during the 1987-1995 period.

No assumption is made as to whether or not China has a static comparative advantage in "pollution-intensive" goods. Changes in relative world prices are simply measured as changes in China's net barter terms of trade.[10] Assessing trade restrictions at an aggregated level is notoriously difficult. For this test, we use the black market premium (BMP) as a proxy for overall trade restrictiveness. Although China has some restrictions on trade which differ across provinces, we assume that their effect is mitigated by free inter-provincial trade. During the 1987-1995 period, China made many significant changes in its regulation of foreign trade. It also shifted its exchange rate regime to a new system of managed floating in 1991 (World Bank, 1994). The BMP shows a sharp increase through 1989, followed by a fairly steady decline, to a low of 5% in 1995.[11]

Estimation and Results

The model in (7) and (11) is estimated using two-stage least squares. Because of the political events of 1989, annual growth rates of variables are calculated from 1987-1989, and from 1990-1995[12]. In addition, since the average rates of growth of emissions and income across provinces are likely to differ based on variation in the types of industries concentrated in a province, fixed effects are included. Estimation of the model also required correction for

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industrial employment.

[10]Data are from the World Bank, *World Development Indicators*.

[11]Data are from the *World Currency Yearbook*.

[12]Data for COD emissions in 1990 are missing. Annual growth of COD emissions for 1991 is approximated by taking one half of the growth rate between 1989 and 1991.

groupwise heteroskedasticity in both equations, and first order autocorrelation in (7). Changes in China's domestic terms of trade are split into two components--changes in the terms of trade measured in world prices ("world terms of trade") and changes in the BMP. Since the latter is an imperfect proxy for the degree of Chinese trade liberalization, the coefficients of the two components are not constrained to be equal.

The results in the first two columns of table 3 appear to validate the hypotheses outlined above. An improvement in world terms of trade has no significant effect on the growth rate of emissions. However, if the drop in the BMP is 1% larger, the growth rate of emissions rises by .07%. To the extent that a larger reduction in the BMP implies an increase in the relative price of exports, this result suggests that China may indeed have a static comparative advantage in pollution-intensive goods. Hence, the direct impact of trade liberalization on the composition of output may indeed lead to a worsening of the water pollution problem.

At the same time, however, trade liberalization increases the growth of income (second column). The lagged BMP reflects the overall level of trade restrictiveness at the beginning of period t. A 1% reduction in trade restrictiveness produces an increase of .03% in the growth rate of income. Turning to column 1 again, we see that a .03% increase in the growth rate of income causes a decline in the growth rate of emissions by $(-.31 \times .03) = -.009\%$. As was argued above, this negative relationship between income growth and emissions growth would reflect the "technique effect." As income rises, people increase their demand for a clean environment, hence further restricting industry's ability to pollute the water. The indirect role of trade liberalization, via its effect on income growth, is to reduce the water pollution problem.

The model in (7) and (11) does not correct for the influence of state ownership of industry. If SOEs are generally less efficient than privately owned firms, equation (5) could be rewritten as:

$$X_i = A(t)\ s^{-1}\ h_i\ [F(L,K),\ E] \qquad (5)N$$

where s is the percentage of industry which is state-owned, and 0<s<1. This would imply

$$\hat{Y} = a_D \hat{D} + a_F \hat{F} + b(t) - \hat{s} \qquad (7)N$$

Thus, an increase in the percentage of state owned industry in a province should result in a reduction in the annual growth of provincial output.

If an increase in the levy has less of an impact on an SOE, because the SOE faces a soft budget constraint, this could be modeled as an implicit subsidy to emissions. Suppose we consider $\tilde{t} = t(1-s)$ to be the effective levy facing the firm. Then $\hat{t}$ is replaced by ($\hat{t}$ - $\hat{s}$) in equations (8) - (10), and ¦?¦ is replaced by (1-s)¦?¦ in equation (8). Equilibrium emissions growth is then:

$$\hat{D} = [e_{tw}/(1-s)|q|](\hat{p}_1 - \hat{p}_2) - e_Y \hat{Y} \qquad (11)N$$

One can see in equation (11)N that a rise in the relative price of dirty goods will have a greater impact on emissions growth, the larger the percentage of state-owned industry.

Results of the estimation of (7)N and (11)N are reported in the last two columns of table 3. Equation (11)N also includes a dummy variable for 1994-1995 during which their appeared to be an economy-wide slowdown in income growth. The degree of state ownership is measured by the share of industrial value added produced by state owned enterprises. The impact of the correction for state ownership in equation (10)N is to reduce the responsiveness of emissions growth to both the change in terms of trade and the change in BMP. A 1% larger drop in the

BMP will now raise the rate of emissions growth by only .02%. This suggests that ignoring state ownership leads to overstating the degree to which a change in the domestic terms of trade will accelerate emissions growth. At the same time, this correction has increased the degree to which income growth reduces the rate of emissions growth (from -.31% to -.42%). The poor fit on this equation overall, however, suggests that the simple small country two-good trade model may be inadequate to capture fully the determinants of equilibrium emissions growth.

Correcting for state ownership and the end of period slump in growth has dramatically improved the fit of equation (11)N. The direct effect of a 1 % increase in state ownership is a reduction in the growth rate of income by 1.59%. Accounting for state ownership has also magnified the favorable effect of a drop in the BMP on the growth rate of income. Thus, from (11)N, a 1% drop in the BMP would now raise the growth rate of income by .06%. Using (10)N, this .06% increase in income growth would then reduce emissions growth by (-.42*.06)= -.025%.

How can the net effect of trade liberalization on emissions growth be assessed? One possibility is to consider a counterfactual scenario where a major trade (or foreign exchange) regime reform which actually took place during the period is omitted. In this case, the most significant reform would likely be the 1991 shift to a managed float exchange regime, which was followed by a sharp decline in the BMP. Thus, the counterfactual considered here holds the BMP to 1990 levels after 1990. Three simulations are run, using the system in (7)N and (11)N. Figure 1 shows actual annual income growth (solid line) for each of the 28 provinces. Each graph also shows predicted income growth represented by the small dashed lines. One can see that the predictions of the model follow somewhat well the actual income growth for most of the provinces. The larger dashed lines then reveal the rate of income growth under the counterfactual of no change in the foreign exchange regime post 1990. In virtually all 28 cases, the results suggest that the rate of income growth would have fallen below the actual rate from 1991 onward, if there had been no change in the exchange rate regime.

Figure 2 shows the results of the same simulations done for emissions growth. Given that the emissions growth equation has a poorer fit than that of income growth, it is not surprising that the predicted emissions growth rates (small dashed lines) do not follow actual growth rates (solid lines) as well. The counterfactual rates (large dashed lines) show consistently less variation than both actual and predicted rates post 1991. In more than half the provinces, this means a higher rate of emissions growth during the 1992 to 1994 period, than both actual rates and predicted rates.

Figure 3 presents the results of this counterfactual exercise for the growth of emissions per unit of industrial value-added (D/Y). For a majority of the provinces, the predicted growth rates of D/Y are quite close to the actual rates. Interestingly, in almost every case, the counterfactual scenario generates rates of growth in D/Y which are higher than those predicted by the model, and in a number of cases are higher than the actual rates.

The ability to draw firm conclusions about the impact of China‟s foreign exchange reforms on overall water emissions growth is somewhat marred by the poor fit of the emissions growth equation. However, the counterfactual results, particularly with respect to emissions per unit of industrial value-added, do suggest that China‟s water pollution problem may have been more severe in the absence of the reform between 1992 and 1995. Thus, the beneficial technique effect of income growth generated by trade liberalization may have dominated the detrimental composition effect generated by that same liberalization.

V. Conclusion

Recent events such as the negotiation of the NAFTA have brought out concerns on the part of both industrial and developing countries as to the effects of trade liberalization on the environment. For the latter group, concern has focussed on the idea that less stringent environmental standards will imply a comparative advantage in pollution-intensive goods. If so, trade liberalization will harm the environment.

Existing empirical work on this question consists of single equation models which focus on the static relationship between trade and environment. That work shows either no relationship between the pattern of trade and relative abundance in environment, or a beneficial relationship between growth of environmental damage and openness. This paper develops an alternative simultaneous equations model which allows for both direct effects of trade liberalization on the growth of environmental damage via changes in relative prices, and indirect effects via the effect of trade liberalization on income growth. In this way, the literature on trade and growth as well as that on income growth and environmental damage (the inverted-U hypothesis) are incorporated into the model. This highlights the fact that trade liberalization indirectly affects relative factor abundance, since the "supply of environment" at any point in time is endogenous.

What emerges is a two equation model which simultaneously determines growth of income and growth of environmental damage. Estimation of this model using Chinese provincial data on water pollution shows the importance of using a simultaneous model to discern the influence of trade liberalization. Results show that there are indeed both a direct and indirect effect of trade liberalization on emissions growth, and that these effects are of opposite sign. Improvements in the domestic terms of trade lead to increased emissions growth. Hence, the composition effect of trade liberalization is detrimental to the environment. However, results also indicate that increased openness significantly raises the growth of income, and that growth of income has a negative and significant effect on emissions growth. Thus, the technique effect of income growth, generated by trade liberalization, is beneficial to the environment. After correcting for biases introduced by state ownership, the detrimental effect of trade liberalization is reduced, while the beneficial effect is magnified.

To assess the net impact of trade liberalization on environmental damage, several simulations were run assuming that China did not undertake the liberalization of its foreign exchange regime in 1991. The results suggest that emissions per unit of value-added would have grown more rapidly in many provinces between 1992 and 1995, had the reform of the exchange regime not taken place. Hence, it appears that the beneficial effect of trade liberalization may have outweighed the detrimental effects during this period.

Further refinements in testing are called for. Confining the test to a two-good small country model is clearly a limitation. This is particularly true because it implies that the price of environmental damage is determined by world markets. To the extent that China is large, that price could be determined locally. This may partly explain the poor fit of the equation estimating growth in environmental damage. In addition, the black market premium is an imperfect proxy for the aggregate level of trade restriction in any economy. It would be useful to see whether or not these results are robust to the use of other proxies. However, despite these limitations, the results suggest that trade liberalization may have significant beneficial effects on the environment via its effect on aggregate income. The fear that developing countries who liberalize trade will become pollution havens is overly pessimistic.

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Province Name	GDP per capita[a]	Growth of Industrial Value-Added[b]	Growth of Industrial C.O.D. Discharge[c]	Total Investment	Growth of Total Employment	Share of Industrial Value-Added from SOEs
Anhui	1.43	20%	-1%	21%	3%	51%
Beijing	5.36	11%	-4%	28%	1%	59%
Fujian	2.58	25%	2%	23%	3%	37%
Gansu	1.22	11%	12%	22%	2%	77%
Guangdong	3.31	23%	-7%	27%	1%	35%
Guangxi	1.42	20%	11%	26%	2%	63%
Guizhou	0.92	9%	11%	25%	3%	74%
Hebei	1.9	15%	-1%	21%	2%	45%
Heilongjiang	2.46	8%	9%	22%	2%	77%
Henan	1.41	19%	11%	21%	3%	49%
Hubei	1.88	16%	3%	18%	1%	57%
Hunan	2.36	13%	-1%	22%	2%	57%
Inner Mongolia	1.69	13%	77%	32%	2%	72%
Jiangsu	3.06	18%	0%	16%	1%	29%
Jiangxi	1.38	14%	-3%	19%	3%	60%
Jilin	2.07	9%	2%	21%	2%	68%
Liaoning	3.3	12%	-3%	19%	1%	56%
Ningxia	1.53	14%	76%	39%	3%	76%
Qinghai	1.67	12%	-1%	49%	2%	84%
Shaanxi	1.34	10%	12%	25%	2%	66%
Shandong	2.39	20%	8%	19%	2%	38%
Shanghai	8	11%	-11%	18%	0%	59%
Shanxi	1.64	14%	1%	25%	2%	57%
Sichuan	1.4	15%	14%	21%	2%	56%
Tianjin	4.5	12%	-3%	17%	1%	53%
Xinjiang	2.24	15%	28%	48%	2%	77%
Yunnan	2.36	15%	5%	31%	3%	75%
Zhejiang	3.26	23%	-7%	19%	1%	25%

Table 2. Trends Over the Period 1987-1995

	Percent Change in:			
Province Name	Levy on Wastewater Collected	Wastewater Discharged	Discharge Intensity[a]	Share of Manufacturing Value Added from SOEs
Anhui	171%	11%	-67%	-30%
Beijing	74%	20%	-48%	-16%
Fujian	186%	5%	-71%	-35%
Gansu	151%	-1%	-34%	-18%
Guangdong	261%	56%	-85%	-31%
Guangxi	304%	19%	-27%	-34%
Guizhou	99%	-30%	-70%	-12%
Hebei	50%	-6%	-50%	-17%
Heilongjiang	105%	-9%	-51%	-14%
Henan	85%	11%	-22%	-25%
Hubei	48%	20%	-1%	-28%
Hunan	-39%	-24%	-50%	-24%
Inner Mongolia	56%	5%	-53%	-16%
Jiangsu	29%	-22%	-61%	-15%
Jiangxi	20%	0%	-46%	-18%
Jilin	28%	5%	-50%	-9%
Liaoning	59%	-1%	-55%	-20%
Ningxia	102%	17%	74%	-9%
Qinghai	94%	-11%	-85%	1%
Shaanxi	84%	20%	-13%	-11%
Shandong	37%	20%	-35%	-20%
Shanghai	-15%	12%	-73%	-35%
Shanxi	28%	-22%	-76%	-19%
Sichuan	39%	-11%	-48%	-27%
Tianjin	100%	41%	-60%	-36%
Xinjiang	273%	103%	72%	-9%
Yunnan	230%	53%	-52%	-8%
Zhejiang	195%	25%	-74%	-19%

[a]Discharge intensity is measured in tons per million yuan of output.

Table 3: The Impact of Openness on Growth of Emissions

Model:	(7)	(11)	(7)N	(11)N
Dependent Variable:	**Emissions Growth** [a,b]	**Income Growth** [a,b]	**Emissions Growth** [a,b]	**Income Growth** [a,b]
Emissions growth	---	-0.01 (-0.76)	---	0.03 (0.31)
Income growth	-0.31* (-2.09)	---	-0.42** (-2.95)	---
World terms of trade (% change)	-1.48 (-0.94)	---	-0.26 (-0.49)	---
Labor force growth	---	-0.07 (-0.20)	---	0.76** (2.31)
Investment $_{t-1}$	---	0.22* (2.18)	---	0.26* (1.80)
Black market premium $_{t-1}$ (level)	---	-0.03** (-3.94)	---	-0.06** (-8.25)
Black market premium (% change)	-0.07** (-2.86)	---	-0.02** (-2.48)	---
SOE growth	---	---	---	-1.59** (-13.34)
Dummy 1994-1995	---	---	---	-8.83** (-6.07)
	N=168 R^2=.34 DW= 2.15	N=196 R^2=.46 DW=1.83	N=168 R^2=.34 DW=2.06	N=168 R^2=.93 DW=1.72

t-statistics in parentheses

**Significant at the 1% level
*Significant at the 5% level
[a] All variables are measured in annual percent change except black market premium $_{t-1.}$
[b] Includes fixed effects for provinces. Estimates of the constant terms are not reported. Hainan and Tibet were excluded due to lack of data.

Figure 1. Income Growth: Actual, Simulated, and Counterfactual

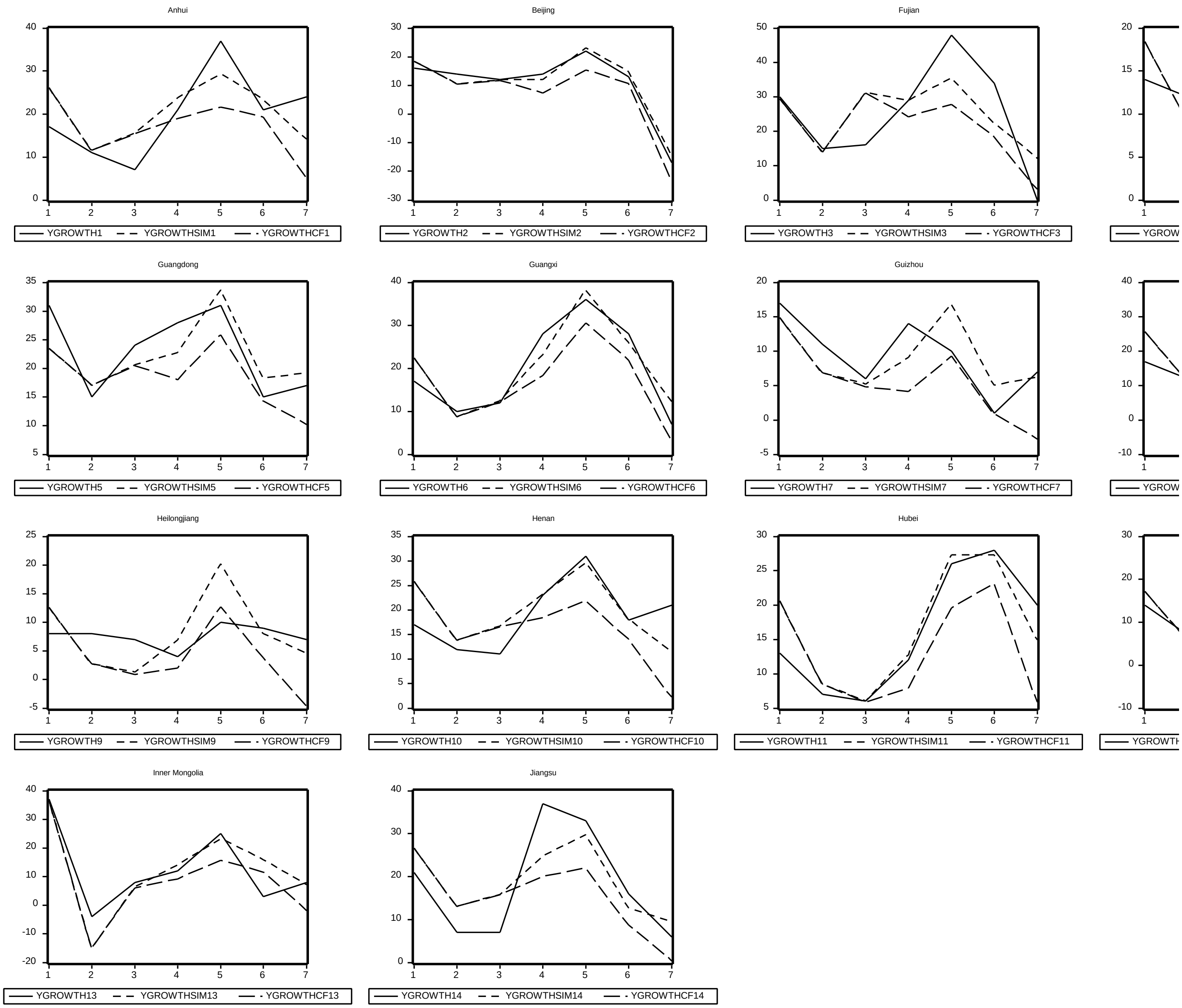

Figure 1 continued.

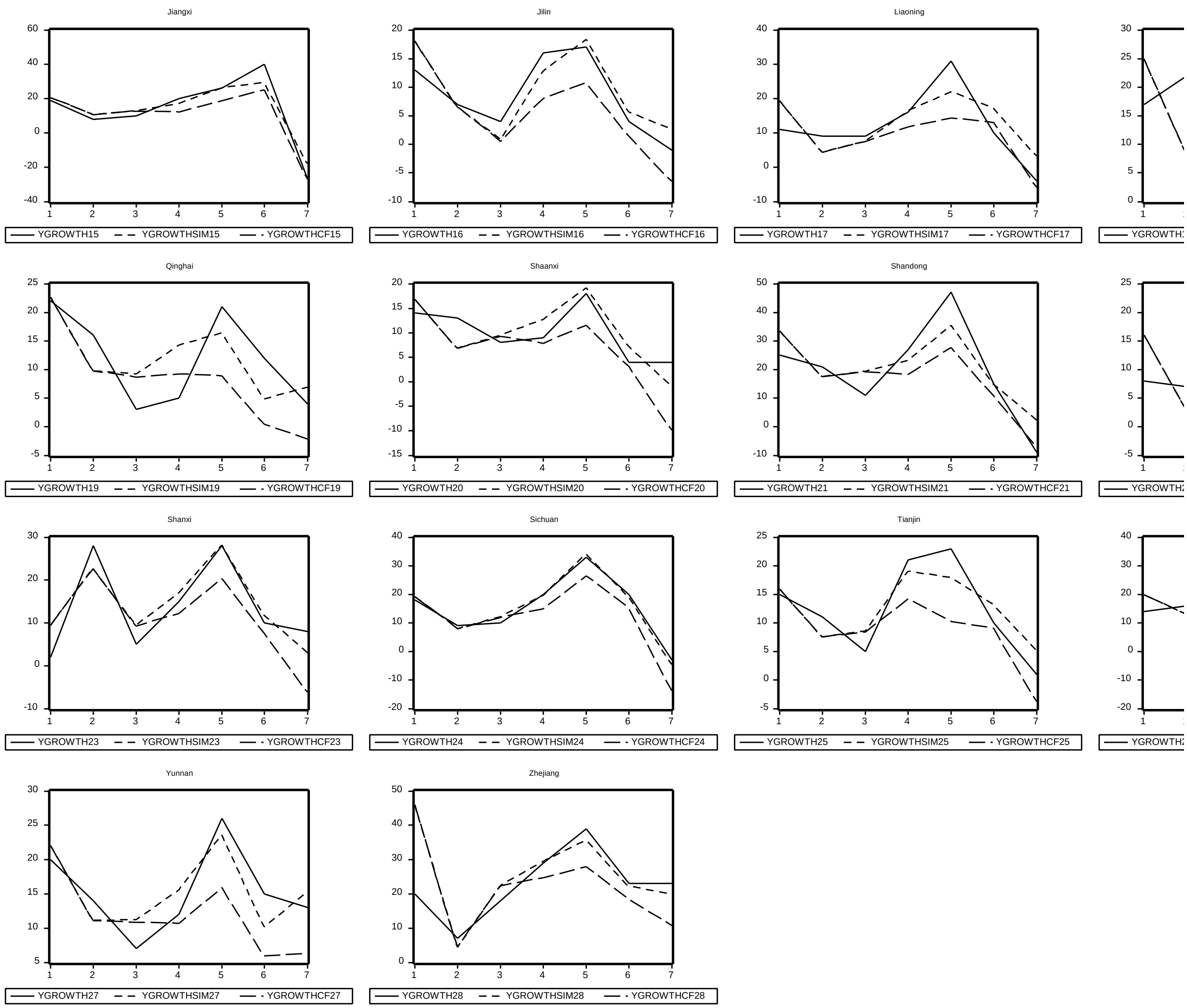

Figure 2: Emissions Growth: Actual, Simulated, and Counterfactual

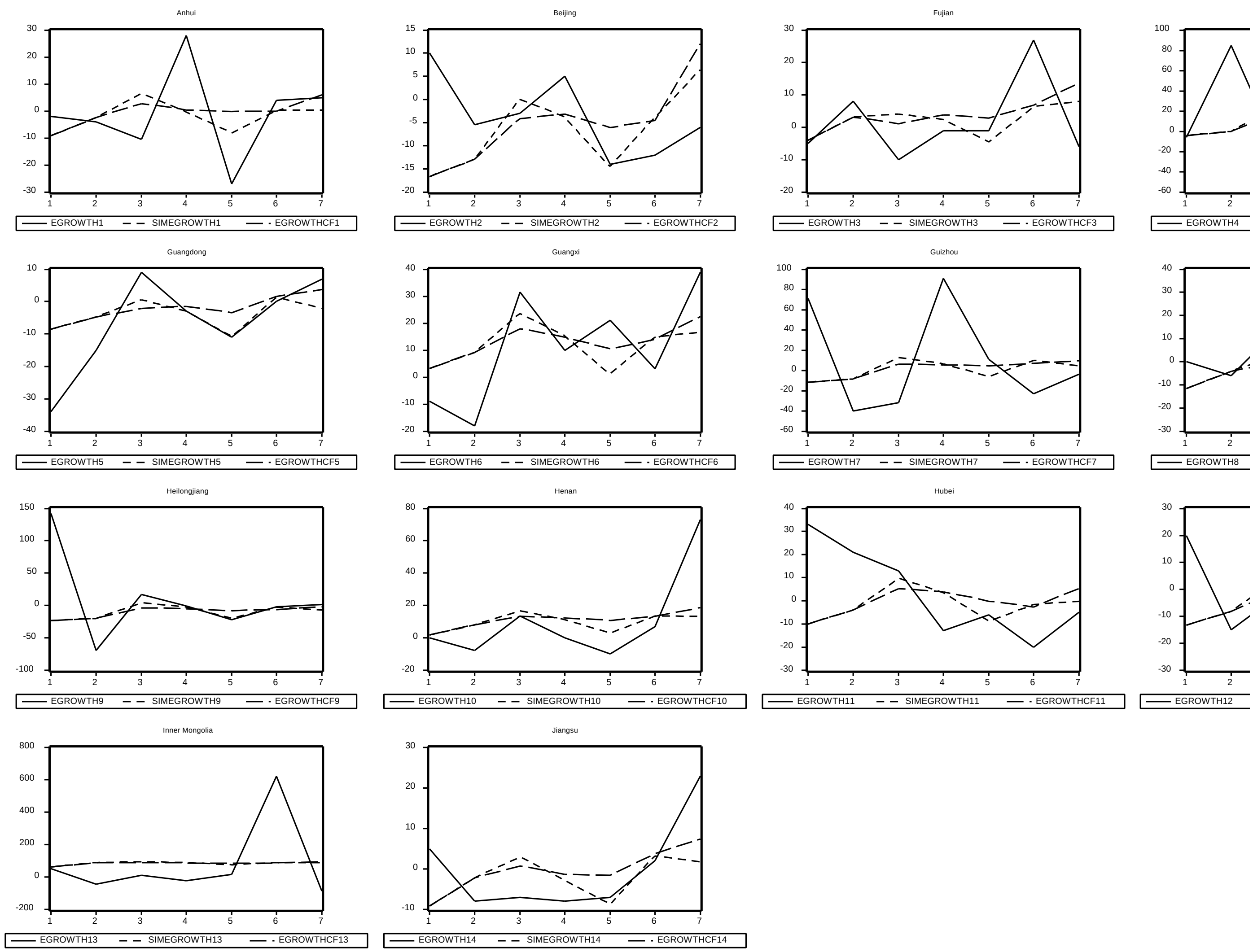

Figure 2 continued.

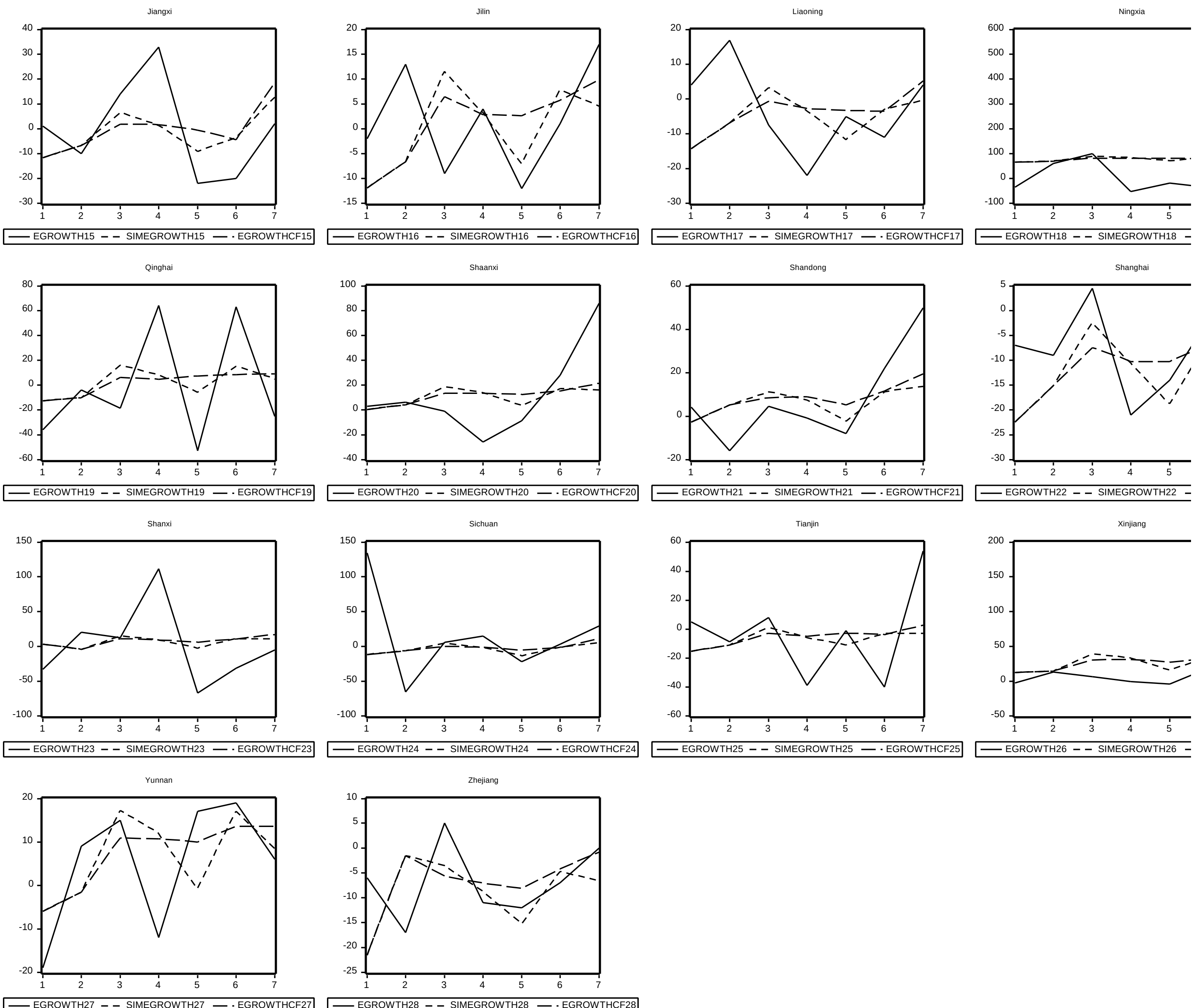

Figure 3. Growth of Emissions per Unit of Industrial Value-Added:
Actual, Simulated, and Counterfactual

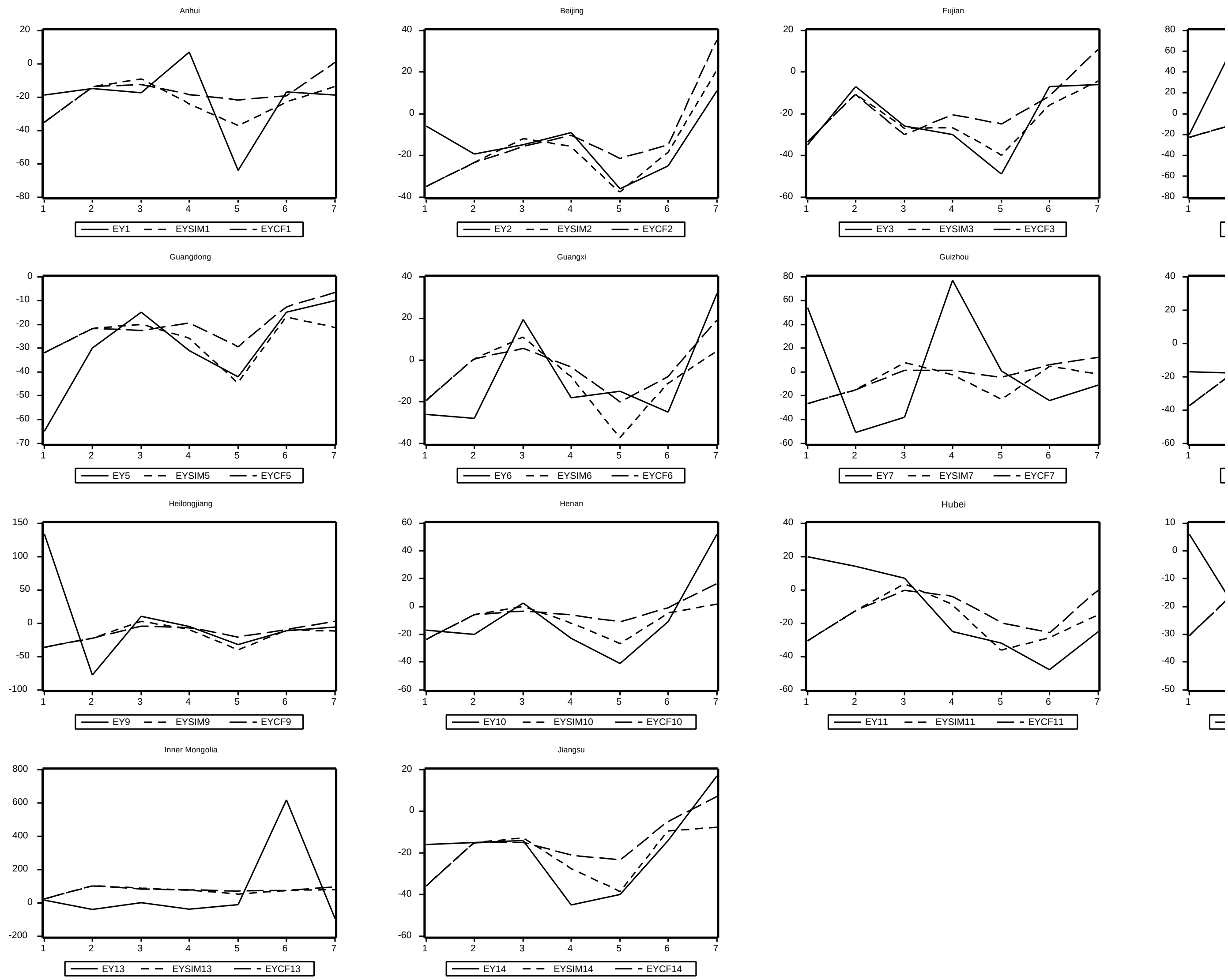

Figure 3 continued.